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Analysis of the JSF Engine Competition

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Outline

- **Background**
- Additional investments for second engine
- Potential price benefits
- Break-even analysis
- Other benefits of competition
- Conclusions

Background

- The John Warner Defense Authorization Act for Fiscal Year 2007 directed the Secretary of Defense to select a Federally Funded Research and Development Center (FFRDC) to conduct an independent cost analysis of the Joint Strike Fighter (JSF) engine program
- The Office of the Under Secretary of Defense for Acquisition, Technology and Logistics selected the Institute for Defense Analyses (IDA) as the FFRDC
- This briefing summarizes the findings of the 2007 IDA study* in non-proprietary form

*Woolsey, J. et al. (2007). (U) *Joint Strike Fighter (JSF) Engine Cost Analysis: final report* (IDA Paper P-4232). Alexandria, VA: Institute for Defense Analyses. Unclassified (PI/LR/FOUO).

JSF Engine Program

- Planned to provide competition between two interchangeable engines
  - F135
    - Pratt & Whitney (P&W) engine
    - Started System Design and Development (SDD) in 2001
    - Flew on the first F-35 aircraft in December 2006
  - F136
    - Fighter Engine Team (FET)—General Electric (GE) and Rolls Royce—engine
    - In SDD since 2005
    - Scheduled for first flight in October 2010 (2007 plan)
    - SDD contract canceled and program terminated in 2011
- Program structure was consistent with successful competitions
  - Planned quantities were high (half of the planned total represents a large quantity by historical standards)
  - History suggested the FET would be price competitive with P&W

Analysis Scope

- ***Investments to create a second engine:*** an estimate of the costs required to develop, procure, and maintain a second engine, before accounting for the benefits of competition
- ***Potential price benefits:*** a review of estimated savings produced by competition in previous programs
- ***Break-even analysis:*** an estimate of the savings that competition must produce to offset the required investment
- ***Other benefits of competition:*** an evaluation of potential benefits other than price reductions that might be produced by competition
- ***Conclusions***

Ground Rules and Assumptions

- Analysis for unique components only (no lift fan, nozzle, roll posts)
- Procurement profiles for U.S. and international partners are from the 2006 JSF Selected Acquisition Report
- Analysis did not include costs and benefits to international customers or future U.S. applications
- Costs through FY 2007 were considered sunk
- JSF program office ground rules provided baseline for Operations and Support (O&S) cost analysis
- Life-cycle period, 2008–2065

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- **Additional investments for second engine**
  - **System Design and Development (SDD)**
  - **Procurement**
  - **Operations and Support**
- Potential price benefits
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SDD Investment: Costs to Complete

- Largest portion of cost was for the remainder of the FET SDD contract
- Other resources were required to support F136 development
  - JSF prime contractor personnel – support for integration efforts
  - P&W costs –common component integration/hardware
  - Government personnel – program office
  - Fuel and other

Procurement Investment Overview

- Quantity effects (Lost Learning)
  - Assumed 50/50 split in competition quantities
- Rate effects (Overhead)
- Below flyaway
  - Initial spares
  - Depot establishment
  - Other below flyaway
- Government personnel

IDA produced independent cost estimates for both the F135 and F136, including learning curve slopes

Procurement Cost Estimates

F135

Used F135 Flight Test Engine (FTE) #3 actual data

- Costs available by component
- Applied F119 FTE and component learning curve experience to project into future
- Accounted for F119 commonality

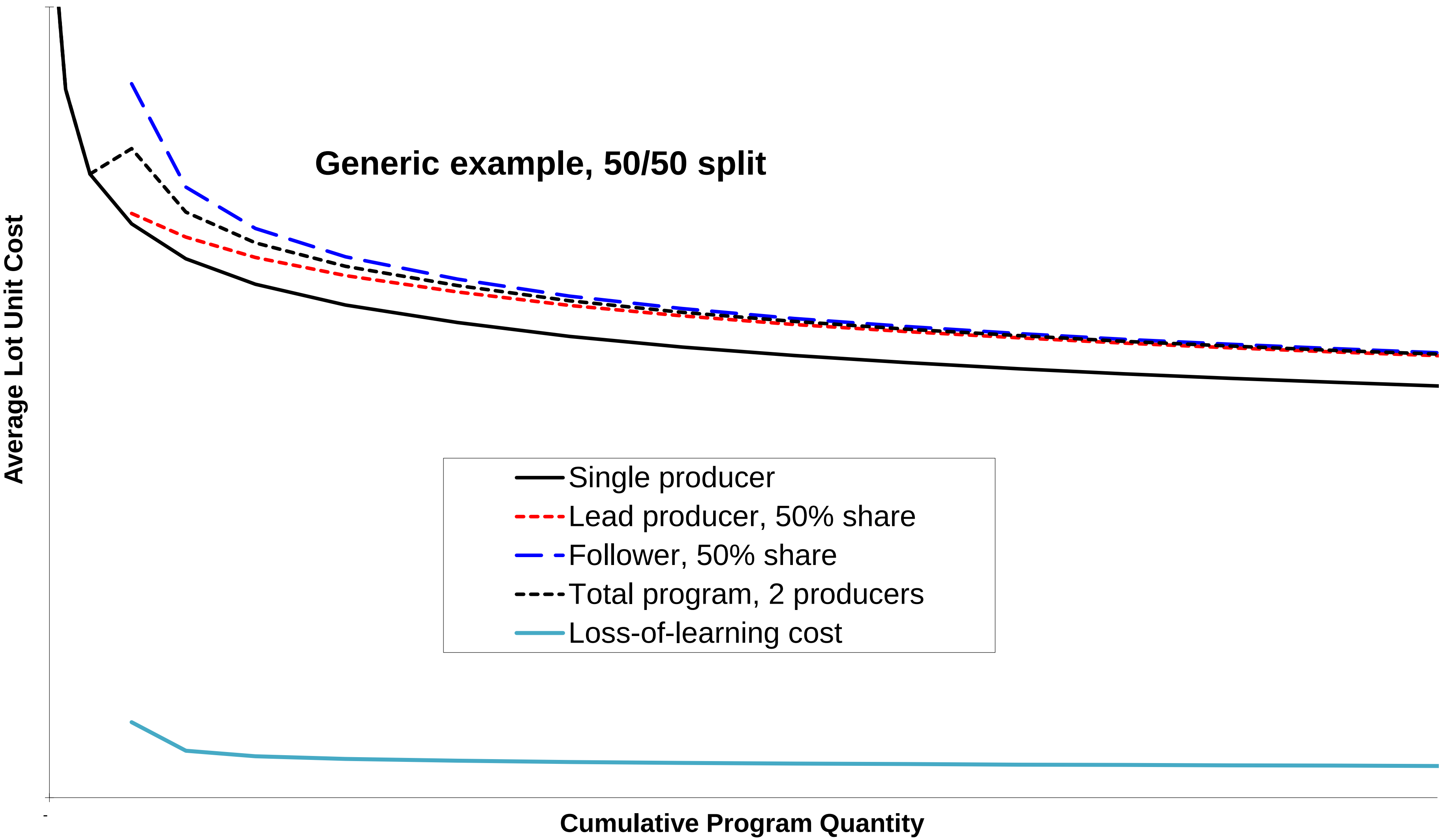
F136

Created component Cost Estimating Relationships (CERs) from previous GE engines

- F101, F110, F404, and F414
- Fan, core, low-pressure turbine, augmentor, and final assembly/other
- Applied F136-specific design data for each component
- Used historic GE price-level learning curves

Estimates indicated the F136 would be price competitive with the F135

Lost Learning



Used sole-source price levels and learning curve slopes to calculate loss-of-learning cost

Overhead Effects

- Moving engines from P&W to FET facilities would affect total overhead costs paid by the U.S. government (including programs other than the JSF); we modeled this effect by assuming:
  - 50% of total costs are overhead
  - 30% of overhead is fixed, based on defense aerospace averages
  - Effects at GE facilities also apply to Rolls Royce content
- Business base projections are from public data
- Analysis shows an increase in overhead cost for dual sourcing the JSF engine
  - $228 million in 2006–2034
  - This may modestly overstate the effects because some overhead impact is captured in the price improvement curve analysis
- Refining this analysis would not materially change overall results

Procurement: Below Flyaway

- ***Initial spares***
  - Two-engine program creates higher spares cost because of higher procurement cost and requirement for two spares pools
  - IDA spares estimating relationship considers:
    - Beddown, procurement cost, and engine removal rates
    - Base re-supply time, depot demand rates, and depot turnaround time
    - Joint Program Office sparing assumptions and spares availability requirement
  - Used JSF program office plan of one spare whole engine per squadron
- ***Depot establishment (and other costs)***
  - Based on F119 cost experience and contractor, F-22 program office, and previous IDA estimates
  - Adjusted for quantity of engines, number of depot locations, and configuration and cost complexity

Operations and Support Investment: Overview

- Variable operations and support
- Fixed operations and support
  - Sustaining engineering/program management
  - Software support
- Component Improvement Program

Variable Operations and Support

- ***Depot-level reparables (DLRs) and consumables:***
  - Sources – contractors, JSF program office, and the U.S. Air Force were sources for reliability and repair cost data
  - Reliability – reliability demand rate estimates were based on Joint Program Office data, P&W data, and aging experience of legacy engines
  - Engine maturity – date of maturity (200,000 flight hours) slips from FY 2015 to FY 2017 in a 50/50 split
  - Repair cost – used repair cost CER based on F-15 and F-16 repair-to-replacement price ratios; used estimated yearly prices as baseline for repair cost, straight-lined at procurement end
  - Maintenance creep – used to increase repair cost in later life to account for aging equipment, reduced quantities, and parts availability issues
- ***Other:***
  - Maintenance manpower – based on Manpower Estimate Reports verified with IDA IMEASURE model
  - Remaining cost elements – based on F119 cost information adjusted for configuration, complexity, and scale of program

Fixed Operations and Support

- ***Sustaining Engineering/Program Management (SE/PM):*** estimated annual fixed cost based on F-119 SE/PM experience and estimated future costs, adjusted for engine complexity and configuration and program scale
- ***Post-Deployment Software Support:*** estimated annual fixed cost using Constructive Cost Model (COCOMO) maintenance model structure with the following input: Source Lines of Code (SLOC), SLOC change and growth rate, productivity, and labor rates

Component Improvement Program

- Annual Component Improvement Program (CIP) funding estimate captures effects of:
  - Size of the engine inventory – the larger the inventory, the greater the payoff for a given upgrade
  - Complexity and size of the engine being supported – engines that are costlier to build are generally costlier to improve
  - Time trend effects:
    - As engine development practices improve, CIP costs decrease
    - As individual engine models mature, CIP requirements decrease
- Estimated average annual CIP funding is $26 million (FY06$) per engine type
- Estimated peak funding of $40 million per engine type occurs in FY 2016

Operations and Support Cost: Summary

	One Engine (F-135) (FY06$B)	Two Engines (50/50 Split) (FY06$B)	Delta (FY06$B)
DLRs and Consumables	19.6	21.2	1.7
SE/PM	0.9	1.7	0.8
Software Support	0.4	0.9	0.4
Engine CIP	1.4	2.6	1.2
Other[a]	11.1	11.7	0.4
Total	33.5	38.1	4.6

Note: Values do not add due to rounding

[a] Other includes maintenance manpower, modifications, contractor logistics support, and indirect support

Second Engine Investment: Summary

- Total investment
  - **$8.8B** constant FY 2006
  - **$5.1B** Net present value (NPV)
- Investment breakdown (FY 2006 dollars)
  - 2008–2012: **$2.1B** (mostly SDD)
  - Operations and Support (O&S): **$4.6B**
  - 2013–2065 residual: **$2.1B** (mostly procurement)

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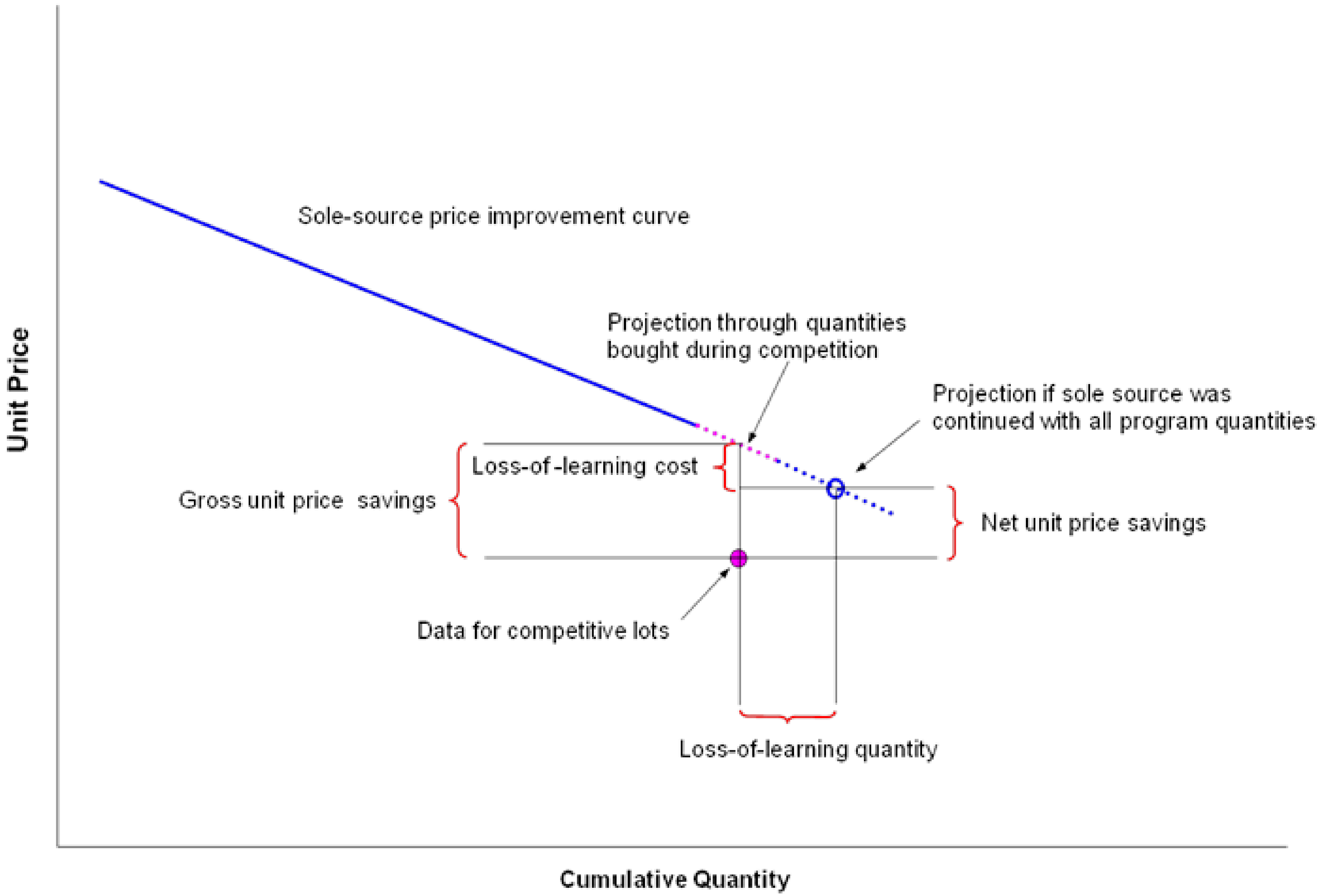
Price Benefits of Competition

- Examined the potential price benefits of competition by analyzing two competitive engine programs
  - Circa 1984: P&W and GE competed for F-16 and F-15 fighter engines (Great Engine War)
  - Circa 1987: P&W used GE design to build F404 engines for the F/A-18
- Reviewed previous studies of competition benefits, but found them to be inconsistent in methodology and supporting material

Generic Example of Competition Savings



- Gross unit price savings were of interest for our analysis
- Loss-of-learning costs accounted for as investment

IDA Estimate of Unit Cost Reductions in Engine Competitions

- ***Great Engine War (GEW):*** IDA estimated cost reductions using two methods
  - Modeled F100-220 as an upgrade of the F100-100 and found estimated savings due to competition
  - Compared the F110 with competition to the F100 without competition
- ***F404 engines:*** IDA estimated GE price reduction during F404 dual sourcing

Competition savings estimates were 11–18%

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Break-Even Analysis

- Required savings from competition: IDA calculated the percentage by which costs must be reduced for second-engine investment to be recovered
  - NPV of savings to offset $5.1B NPV of investment
  - Year-by-year competition
- Competition for procurement: savings calculated on procurement costs only; assumes no mechanism for competition savings in O&S
  - 40% savings on ≈$13B NPV base to offset total investment
  - Not plausible, given analysis of historical programs
- Competition for procurement and O&S: savings calculated on procurement and O&S costs
  - 18% savings on ≈$29B NPV base to offset total investment
  - Range of 15–25% for alternative assumptions

Savings in O&S required for break-even

Competition for Support Services

- Support costs are typically more than half of life-cycle costs and normally incurred in a sole-source environment
- Cost savings from procurement competition will flow to some support costs (spare parts, depot-level repair materials, modifications, etc.)
- Competition would ensure that these support cost savings become support price reductions
- Some competition can be created by using award criteria to tie support elements to procurement (warranties, Performance Based Logistics price quotes, etc.)
- 70–80% of commercial aircraft engines are purchased with support service contracts, which implies that packaged competition is the best value solution for airlines
- JSF program office intends to create an acquisition strategy that ties O&S costs to the procurement competition
- We found no data with which to benchmark potential O&S savings

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Other Potential Benefits of Competition

Competition could produce benefits in the following areas:

- Technical risk
- Product quality
- Force readiness
- Contractor responsiveness
- Industrial base

Competition and Technical Risk

- Because the engine designs were independent:
  - Risks were different
  - Probability of obtaining an engine that meets all requirements would be increased by competition
  - Competition creates other options (e.g., single source on one variant with competition on others)
- Same end might be achieved at lower cost by adding money to existing program
- Sustaining competition would require investment in any deficient engine

Our analysis of the effect of competition on technical risk was inconclusive

Competition and Engine Reliability

- Engines that competed in the GEW were more reliable than the predecessor F100-100 engine
- The competitive engines were not more reliable than their non-competitive contemporaries, the F404 and TF30
- Reliability/durability benefited from changes in the engine development process in the mid-to-late 1970s
  - Accelerated mission testing
  - Four-step development process, incorporating more durability testing
  - Initiation of Engine Structural Integrity Program, damage-tolerant design

The historical evidence was inconclusive as to whether competition has improved engine reliability

Readiness and Engine Grounding Events

- Engine programs have had grounding events that reduced fleet readiness
- Significant examples include:
  - AV-8B
    - 10 events since 2000
    - Most severe event affected 2/3 of the fleet for as long as a year
  - B-1B
    - Entire fleet grounded from December 1990–February 1991
    - Last plane returned to service April 1991
- Presence of two engine types would decrease the impact of similar events on future fighter force readiness

Contractor Responsiveness

- Contractor responsiveness was the primary motivation for the GEW; it is generally agreed that responsiveness improved as a result
- GEW accounts report poor responsiveness from P&W
  - Failure to correct reliability problems
  - High spare parts prices
  - Debatable contract interpretations
  - Negotiating positions during competition
- Evidence of competition's effect can be seen in contract terms negotiated during the GEW
  - Fixed price development contracts
  - Firm price initial production
  - Warranties
  - Data rights for spare parts

GE: Skills Retention

- Some skills and technologies are unique to high-performance military engines (e.g., low observables, flight envelope, thermal management)
- Cancellation of the F136 might threaten these skills at GE:
  - GE’s incentive to maintain such skills would depend on potential future business
  - Bomber replacement and Unmanned Aerial Vehicle/Unmanned Combat Aerial Vehicle are prospects, but uncertain
- Mechanisms for retaining skills include:
  - Retaining individuals with expertise
  - Documenting processes
  - Obtaining DOD Science and Technology funding, which has been done in the past (ADVENT program is a current example)
- There would inevitably be losses of individual and collective knowledge:
  - Some of this could be re-purchased if needed

Other Benefits: Summary

- Analysis of the effect of competition on technical risk is inconclusive
- Effect of procurement competition on product improvement and technical innovation is inconclusive
- A second engine would reduce the impact of an engine grounding event on operational readiness
- History has shown that competition makes contractors more responsive
- A second engine would ensure that GE remains in the fighter engine industrial base

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Conclusions

- Direct investments and opportunity costs inherent in executing a second engine program total $8.8 billion, of which $2.1 billion occurs in years 2008–2012.
- If competition only yields procurement savings, it would have to produce savings of 40% on those costs, an implausible rate compared to the 11–18% savings found in previous engine competitions.
- If O&S costs were effectively competed in addition to procurement, the required savings rate would fall to 18% of total costs.
- Because the Department of Defense has not typically linked O&S costs to procurement competition, we found no historical data with which to benchmark plausible O&S savings.
- Competition had the potential to bring benefits in addition to reduced prices:
  - Force readiness
  - Contractor responsiveness
  - Industrial base breadth

Backups

Lessons Learned

- The JSF engine competition as structured met the necessary conditions for a viable competition
- However, competition between two engine designs presented challenges for economic success
  - Support costs are an important portion of engine lifecycle costs
  - Having two designs requires additional support infrastructure and delays reliability maturation
  - There is a limited track record for engine support competition in DOD
  - Many of the advantages of having two engine designs are not quantifiable as cost savings
- Competition may be easier to justify economically in other cases
  - Equipment types where O&S costs are a small portion of life cycle costs
  - Competition between producers of build-to-print items where support costs are not impacted

Analysis of SDD Contracts

- Examined cost risk on SDD contracts by evaluating F135 and F136 schedule projections
  - Focused on Initial Flight Release (IFR) and Initial Service Release (ISR) milestones
  - Used historical programs to develop Time Estimating Relationship (TER)
  - Compared F135 and F136 to resulting TER
- Schedules appear modestly optimistic based on prior expenditure patterns
- Analysis included an excursion for a SDD extension to show effect of potential F136 schedule slip

One-Time Competition for Life-Cycle Costs

- ***Advantages:***
  - Maximizes the stakes of the competition, potentially encouraging large contractor investments
  - Avoids costs inherent in maintaining two production lines and support infrastructures
- ***Disadvantages:***
  - Contract would have to cover more than 40 years and exceed $60 billion
  - Contract would include extraordinary risks due to inflation, buy quantities, growth engines, aircraft usage, labor rates, etc.
  - Contractor could not assume these risks, so the contract would contain myriad exception clauses
  - Contract would become a series of negotiations with a sole source, eliminating much of the competition’s value
  - Contractor would have an incentive to “buy-in” at an unsustainable price, anticipating future renegotiation (similar to Total Package Procurement contracts, which typically have been unsuccessful)

One-time competition case
was not analyzed quantitatively

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Maintenance Manpower	2.9	2.9	0.0
Contractor Logistics Support	2.9	3.2	0.2
Modifications	3.4	3.7	0.3
Indirect Support	1.2	1.2	0.0
Support Equipment Replacement	0.7	0.7	0.0
Sustaining Engineering Support	0.9	1.7	0.8
Software Support	0.4	0.9	0.4
Engine CIP	1.4	2.6	1.2
Total	33.5	38.1	4.6